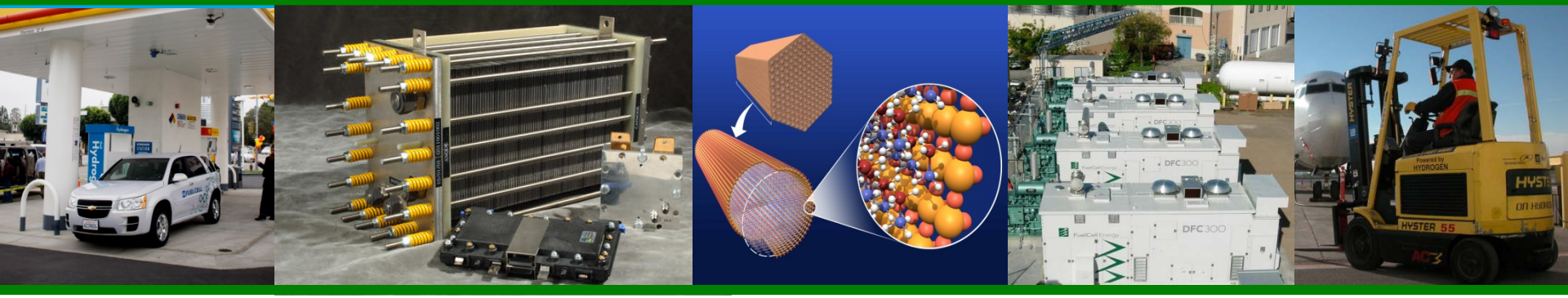
U.S. DEPARTMENT OF ENERGY



Safety, Codes and Standards Program

-Plenary Presentation-

Will James

Fuel Cell Technologies Office

2016 Annual Merit Review and Peer Evaluation Meeting

June 6 - 10, 2016

SCS Program Goal and Objectives

Codes & Standards Objectives:

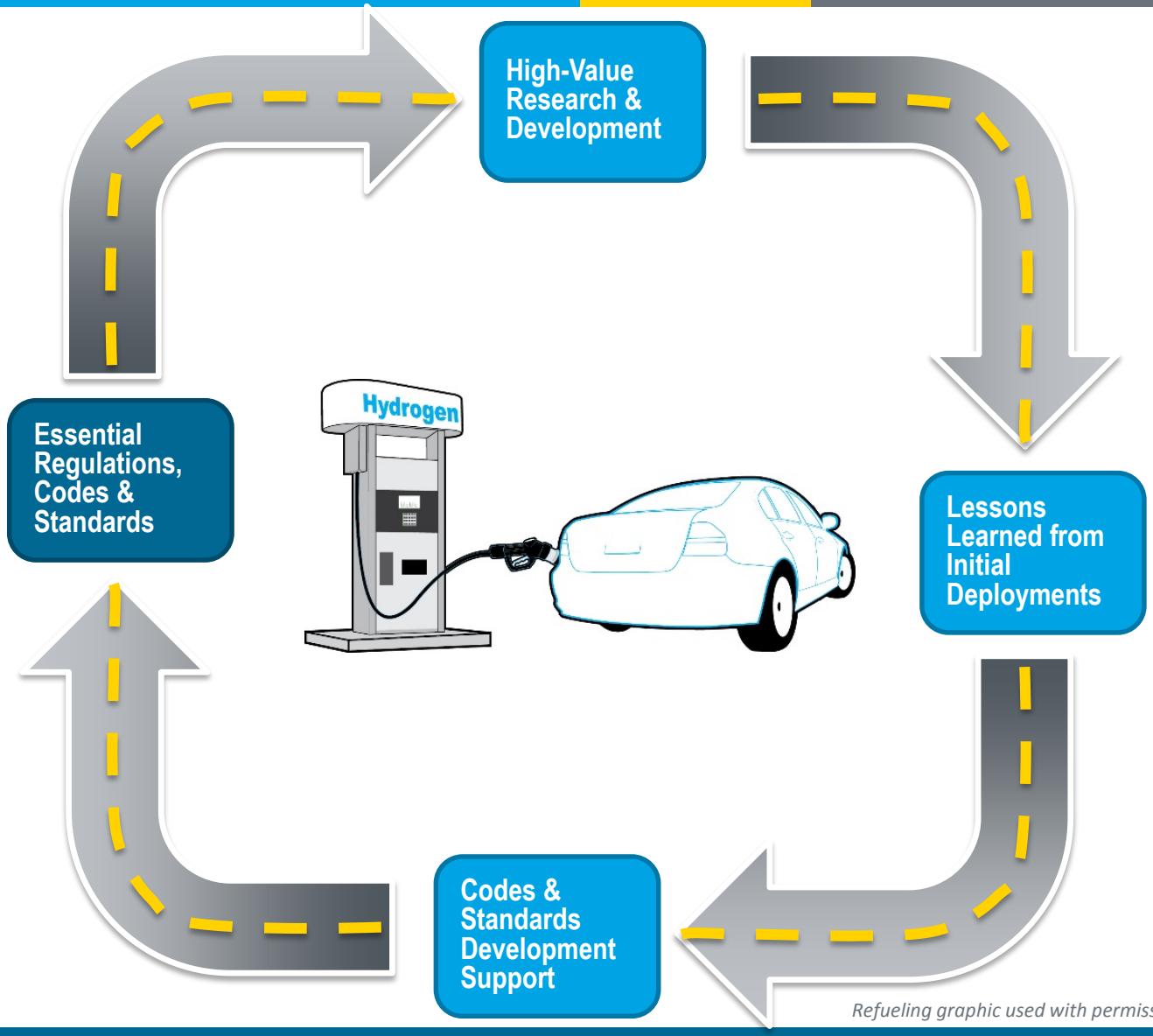
- Support and facilitate development and promulgation of essential codes and standards to enable widespread deployment and market entry of hydrogen and fuel cell technologies and completion of all essential domestic and international regulations, codes and standards (RCS)
- Conduct R&D to provide critical data and information needed to define requirements in developing codes and standards.

Hydrogen Safety Objectives:

- Ensure that best safety practices underlie research, technology development, and market deployment activities supported through DOE-funded projects.
- Develop and enable widespread sharing of safety-related information resources and lessons learned with first responders, authorities having jurisdiction (AHJs), and other key stakeholders.

Enable the widespread commercialization of hydrogen and fuel cell technologies through the timely development of codes and standards and dissemination of safety information

SCS Program Impact



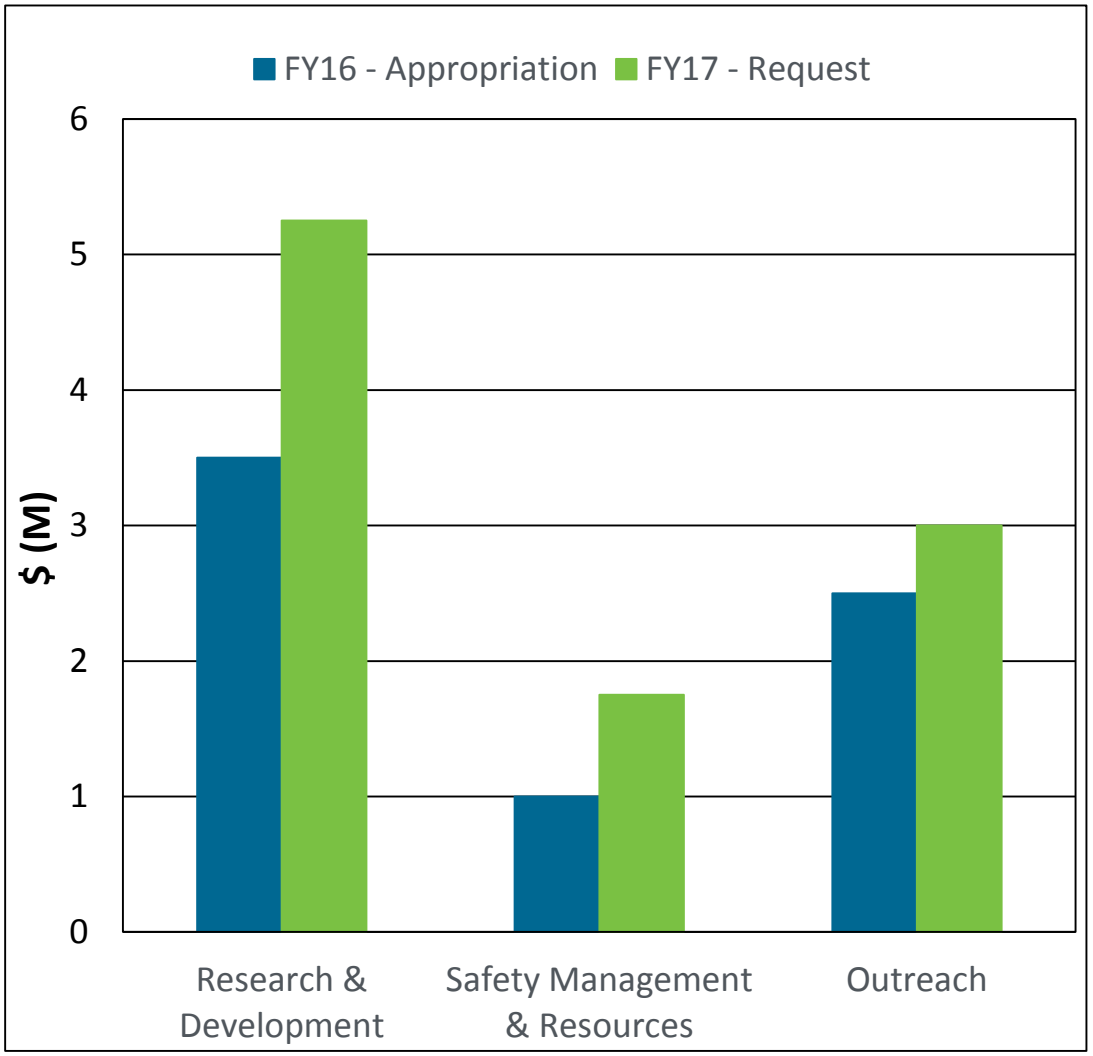
Refueling graphic used with permission from the CAFCP and ISO

Leveraging DOE expertise helps accelerate deployment of H_2 & FCEVs

Budget

FY 2017 Request = $10M

FY 2016 Appropriation = $7M



Emphasis

1. R&D Activities
   - H_2 Behavior
   - H_2 Fuel Quality
   - Sensors
   - Component Testing
   - Materials Compatibility
2. Safety Management and Resources
   - Hydrogen Safety Panel
   - Databases
   - Training Props
3. Outreach
   - Codes & Standards and Permitting
   - Continuous Codes and Standards Improvement
   - Resource Dissemination

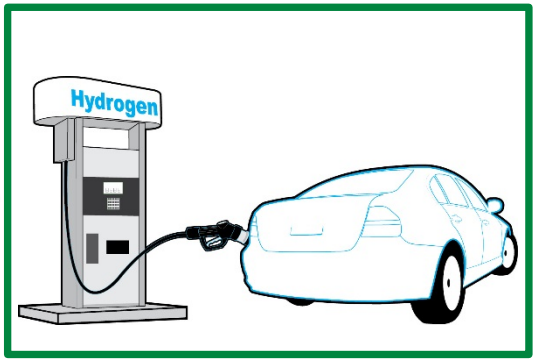
Codes & Standards Approach

Inputs/ Interactions → **Identify and Perform High Value R&D** → **Codes and Standards Implementation** → **Infrastructure Deployment**

- H2USA
- USDRIVE
- hySafe
- IPHE RCSWG
- HIA Hydrogen Implementing Agreement
- ICHS

- Hydrogen Behavior
- Risk Assessment
- Materials Compatibility
- Fuel Quality Assurance
- Sensors

- NFPA
- ICC International Code Council
- SAE International
- United Nations
- ISO
- Department of Transportation United States of America
- CSA Group
- CGA Compressed Gas Association
- ASTM International Standards Worldwide
- UL
- ASME Setting the Standard



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The codes and standards element enables and supports hydrogen station deployment

Hydrogen Behavior & Risk Assessment

Cold Hydrogen Release Lab

Newly completed cryo-temperature laboratory to validate liquid H_2 models to enable risk assessment tools and bring a science-based approach at the code committees.

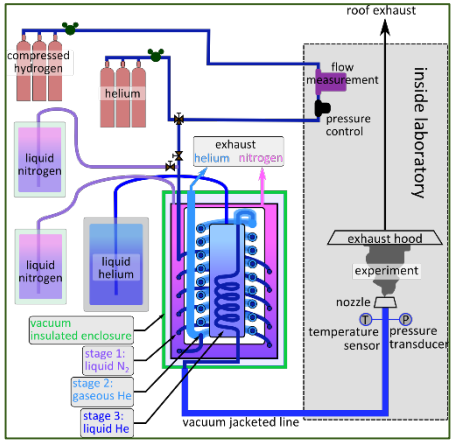
Hydrogen Risk Assessment Models (HyRAM)

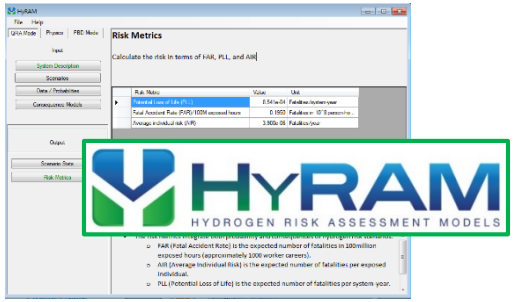
Quantitative risk assessment (QRA) utilizes engineering models to produce risk metrics which enable performance-based design.

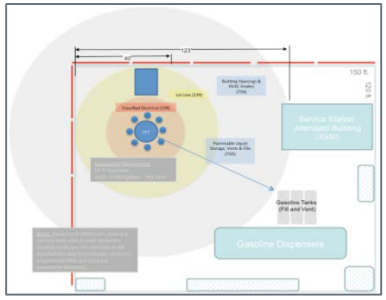
Alternative Compliance Methods

Performance-based design is a risk-enabled (via QRA), NFPA 2 - compliant option for station design.

Station Deployment







- **HyRAM Public Release: Spring 2016!**
  Available for download at http://hyram.sandia.gov
- **DOE Webinar held April 26, 2016**
  (Full recording at http://energy.gov/eere/fuelcells/2016-webinar-archives*)*

Leveraging science to enable infrastructure through understanding hydrogen behavior, analyzing risk, and implementing inherently safe design options.

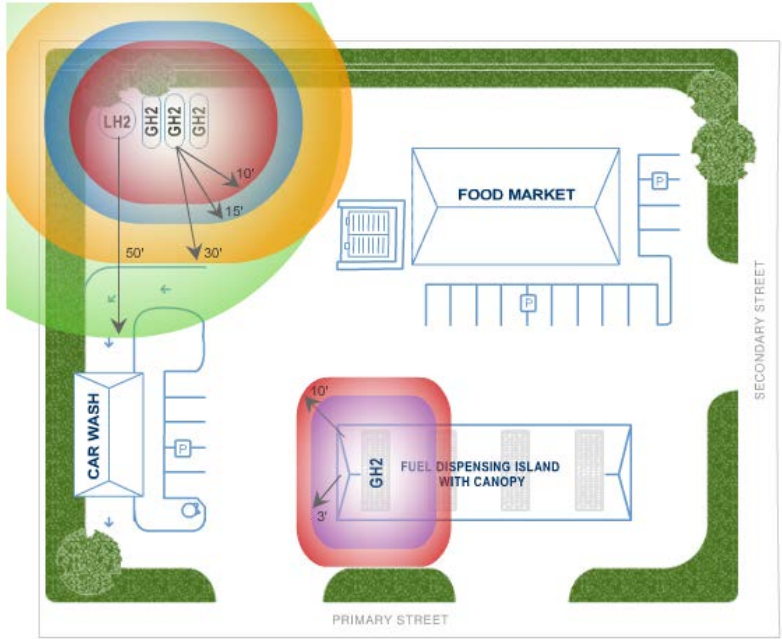
NFPA 2/55 Task Group

Task group made up of representatives from both the national labs and industry

- Utilizing scientific knowledge base to develop recommendations for modification of NFPA 2/55 during the next code cycle
- Developed draft revised setback distances for bulk gaseous hydrogen storage systems, focusing on three parameters (also an added safety factor of 1.5):

    1. *Unignited jet concentration from 4% to 8%*
    2. *Heat Flux level from 1.6 kW/m² to 4.7 kW/m²*
    3. *Leak area from 3% to 1%*

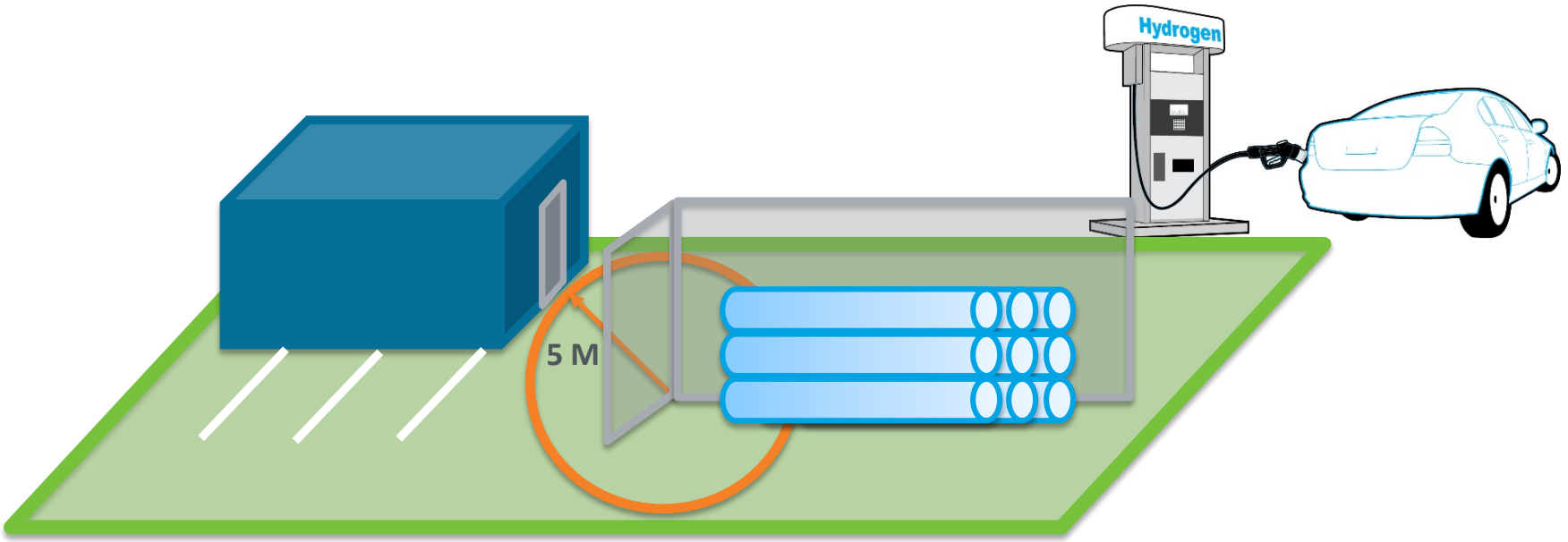
- The group is also considering liquid hydrogen storage setback distances



The work of this task group has the potential to reduce gaseous hydrogen separation distances by an additional 50% in the 2019 edition of NFPA 2.

Hydrogen Behavior Efforts

Objective: Perform the critical R&D necessary to provide a scientific basis for the reduction in both gaseous and liquid separation distances in RCS.



Supporting infrastructure deployment through science-based reduction in separation distances

Safety Sensors

Objective: Develop low cost, low power, durable and reliable H_2 safety sensor for vehicle and infrastructure applications.

1. **Vehicle Repair Facility**: NREL-KPA/Toyota (sensors mandated by IFC)
   - Qualified H_2 safety sensor for repair facilities; 10 deployments (CA); 10 more pending (N.E.)
2. **Infrastructure**: NREL/Element One developed DetecTape - Commercialized and available!
   - DOE Webinar held March 14, 2016 (recording available at *http://energy.gov/eere/fuelcells/2016-webinar-archives*)
3. **Vehicle Tailpipe H_2 Emissions**: NREL, in support of GTR
   - Low-cost sensor identified with rapid response time and range of 0 to 10 vol% H_2

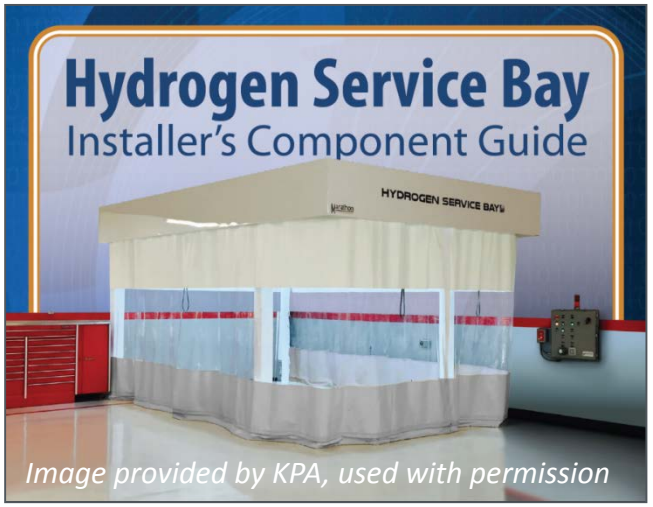


Image provided by KPA, used with permission

Comprehensive R&D on safety sensors is improving safety for FCEVs, infrastructure, and repair garages; all critical components of broad commercialization of hydrogen technology.

Fuel Quality and Fuel Quality Assurance

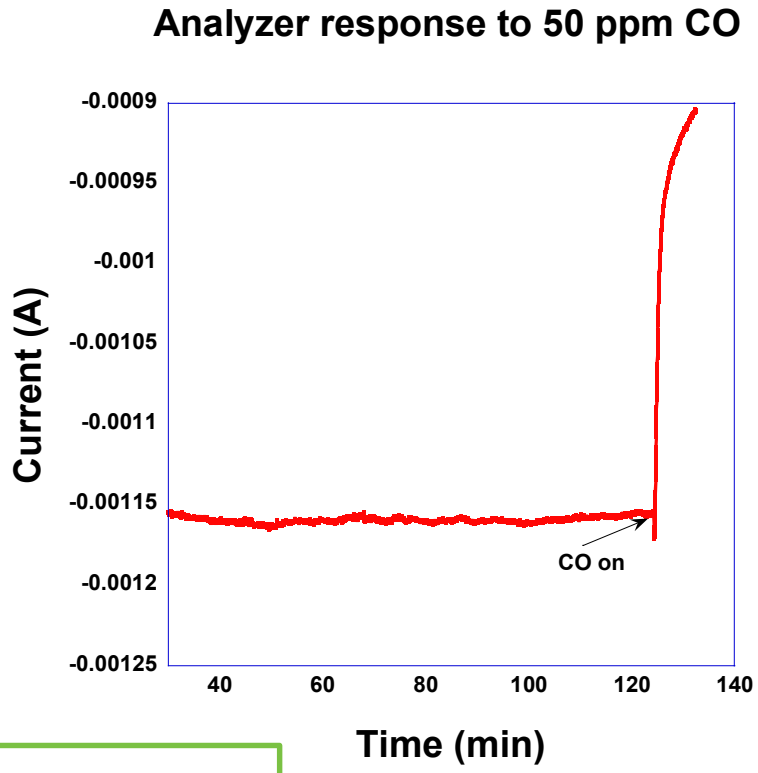
The development of a device to measure impurities in the fuel stream would be beneficial to the fuel cell community, hydrogen fueling stations and suppliers.

Hydrogen Fuel Quality

- International collaborations underway (CEA, VTT, JRC)
  - Baseline testing complete
  - H_2 impurity testing on-going (HyCoRA Project funding extended)

Hydrogen In-Line Analyzer

- New! – prototype developed
- Demonstrated hydration scheme allows for constant baseline measurements
- Instant response observed at 50 ppm CO



Other Ongoing Effort:

SBIR Phase II: Diode Laser Hydrogen Contaminant Detector *(Southwest Sciences)*

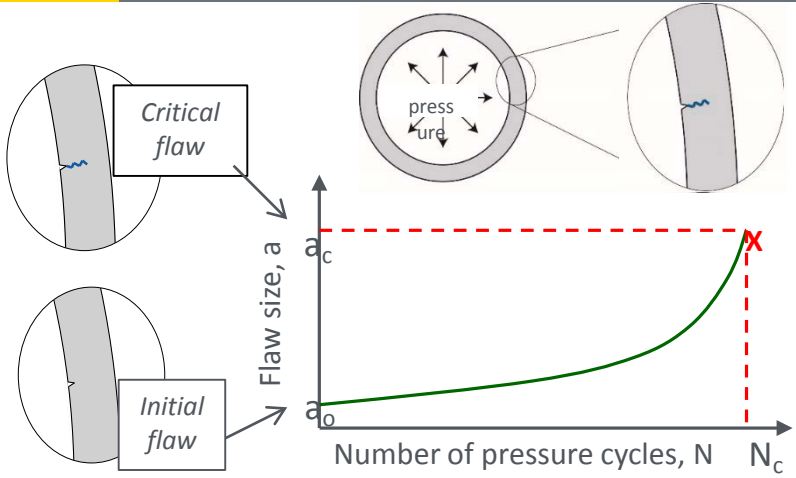
A means of detecting contaminants in the hydrogen fuel stream is vital to ensure quality according to SAE J2719 and prevent damage to the fuel cell.

Hydrogen Compatibility of Materials

Performing critical materials R&D to enable RCS in support of infrastructure deployment

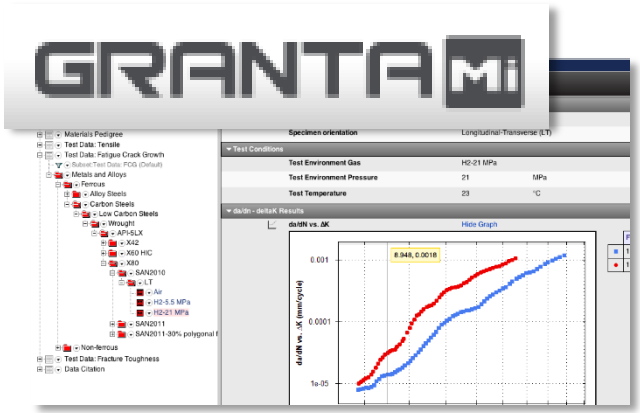
Metallic Materials Compatibility

- Establish coordinated fatigue life testing and data sharing with international stakeholders
- Demonstrate low-temperature fatigue life method for austenitic stainless steels



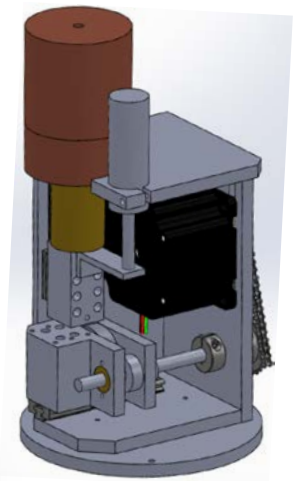
New! - Technical Database for Hydrogen Compatibility of Materials:

- Hydrogen effects database will be made available to Granta-users



New! - Polymer Compatibility

- Filling the critical knowledge gap for polymer performance in H_2 environments

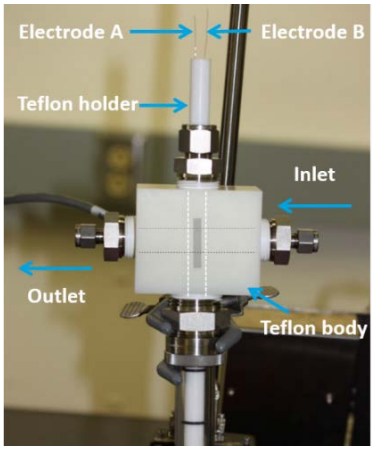


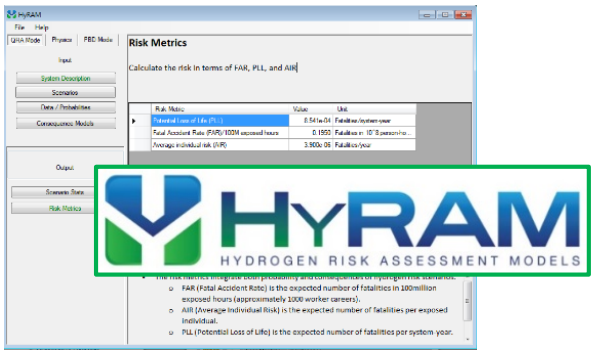
Planned upgrade with vertical LVDT for in-situ wear track measurement

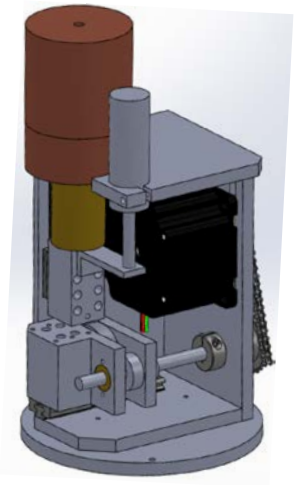
Summary: R&D Progress Since AMR 2015

Continuing to perform critical R&D to enable science-based codes and standards

- Newly completed liquid hydrogen release laboratory now performing behavior experiments **(SCS 010)**
- Expanded materials compatibility efforts to include hydrogen compatibility of polymers **(SCS 026)**
- New NFPA 2/55 task group to develop revised separation distances for gaseous hydrogen storage **(SCS 025)**
- In-line fuel quality analyzer prototype developed **(SCS 007)**
- Hydrogen Risk Assessment Models (HyRAM) released for public use **(SCS 011)**
- Initiated experiments to profile LH_2 releases during venting **(SCS 021)**
- New materials database for hydrogen compatibility data **(SCS 005)**

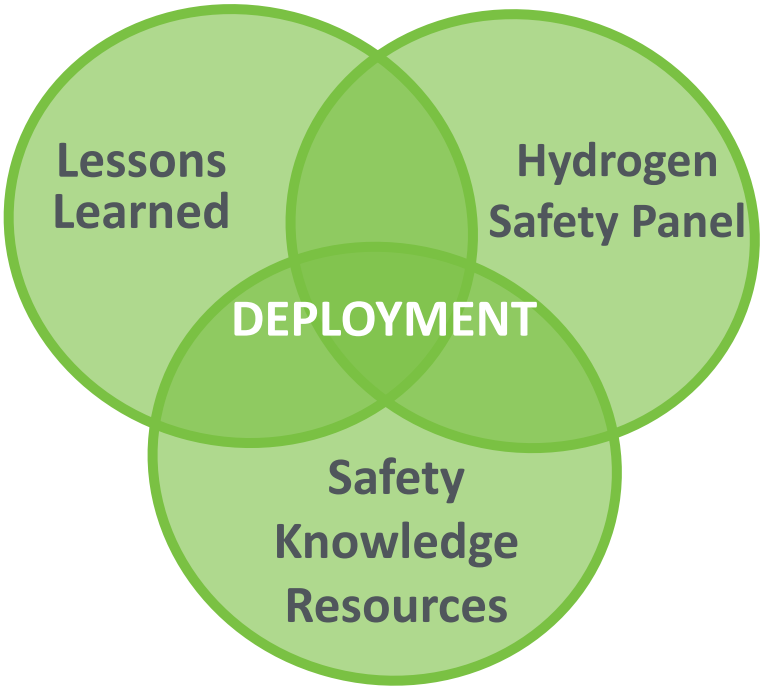






Safety & Outreach Overview

Objective: Ensure that best safety practices underlie research, technology development, and market deployment activities supported through DOE-funded projects



Hydrogen Safety Panel members at the California Fuel Cell Partnership in West Sacramento, CA, for the 21st meeting

Accomplishments:

- H2Tools.org: What's New?
- Stakeholder Outreach Events in the Northeast
- International safety data sharing initiative (IPHE)
- Hydrogen Safety Panel continues to have significant impact on infrastructure deployment!

Safety Outreach & Resource Dissemination

Training Resource	Impact
First Responder Training (in-person)	1,035
First Responder Training (online)*	>32,000
Code Official Training (in-person)	650
Code Official Training (online)	1,357
Hydrogen Tools App Downloads**	1,272
Hydrogen & Fuel Cell Emergency Response Training Resource Downloads	289
Hydrogen Researcher Training (online)	179
H2Tools.org (visits with 2 or more pages viewed)	9,719

- Over 2,400 first responders and code officials reached since AMR 2015

** No longer being tracked; ** no longer being supported*

SCS supports continued code official and first-responder training, both online and in-person, with over 36,000 individuals reached!

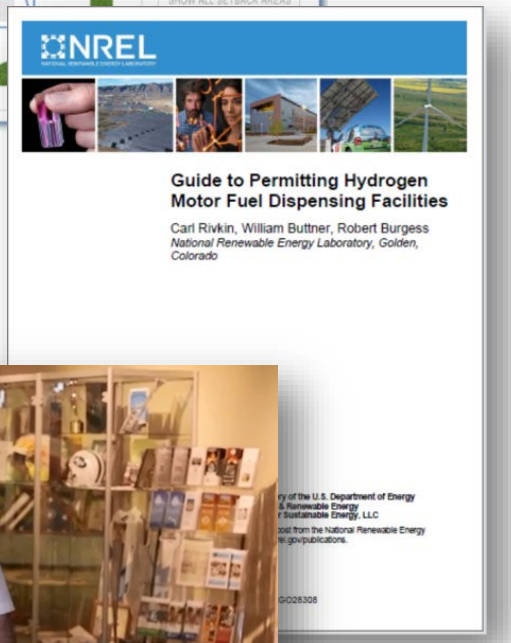
New and Upcoming Outreach Resources

Updating Online Code Official Training

- Objective: make code training easily accessible
- Updates include:
  - Code citations
  - Photos of active installations
  - Interactive station schematic

Permitting Guide

- Enables faster and more efficient permitting with focused and detailed information on hydrogen fueling stations



Permitting Video

- Objective: Reduce difficulty of permit development and review for hydrogen fueling stations.

Outreach Events

International Code Council (ICC) Outreach

- ICC annual business meeting in September 2015
  - Classroom content, Site tour, Expo booth, Ride & Drive event
- Educational session for the ICC Colorado Chapter Educational Institute (March 2016)

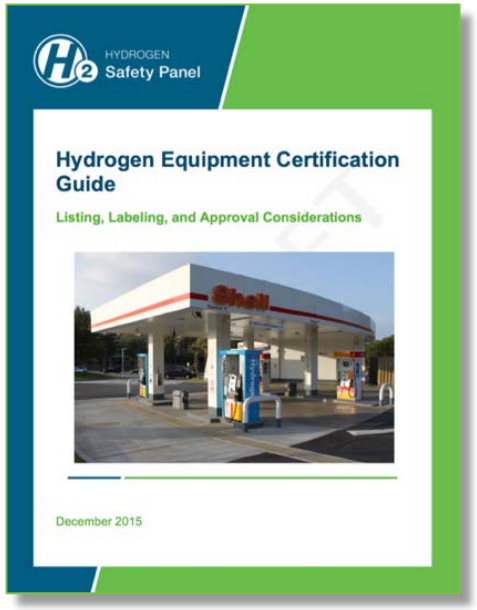
Stakeholder and Code Official Outreach

- U.S. Fire Administration webinar (June 2015)
- Sacramento Fire Prevention Officers (August 2015)
- International Association of Fire Chiefs webinar (September 2015)
- Northeast U.S. outreach events
  - PNNL, NREL, Toyota and Air Liquide (April 2016)
- Washington/Oregon stakeholder outreach (May 2016)

Carl Rivkin (NREL) presents on hydrogen codes & standards to Manhattan AHJs during April 2016 outreach meeting

New Publications and Resources!

- **Hydrogen Equipment Certification Guide (PNNL)**
  - Developed to assist with the application of the listing and approval requirements pertinent to the design and/or installation of hydrogen equipment as regulated by the model codes.
    - DOE webinar held December 10, 2015 (Recording available at *http://energy.gov/eere/fuelcells/2015-webinar-archives*)



- **HyRAM User Guide and HyRAM Algorithm Report (SNL)**
  - Intended to enable use of the HyRAM tool and provide documentation of models and methods used in the software

- **Draft Fire Protection Engineering Design Brief Template (SNL)**
  - Developed to demonstrate the application of performance based design in the permitting of hydrogen refueling stations

SCS International Collaboration

- Active international collaborations with national and foreign labs, universities, private organizations, and energy companies
- Bilateral and multilateral efforts focus on safety training, materials compatibility for high-pressure hydrogen applications, fuel quality, and sensor testing and validation.

- Recent collaboration: Fire fighters from the U.S. attended HyResponse training in May 2016 (shown at right)
  - Held at the French Academy for Fire, Rescue and Civil Protection Officers (ENSOSP)
  - 24 active participants
  - LA County, San Jose, NYC, and Littleton, MA Fire Departments participated

Leveraging international collaboration allows for the development and promulgation of essential codes and standards to enable widespread deployment.

Team Collaborations/Working Groups

International

- IPHE - International Partnership for Hydrogen & Fuel Cells in the Economy
  - 17 countries & EC, 30 projects
- International Energy Agency Hydrogen Implementing Agreement (IEA HIA) Task 37
- Independent Projects (EU, Japan, Korea, etc)

DOE-EERE Safety, Codes and Standards

Industry Partnerships & Stakeholder Assn's.

- Tech Teams (USCAR, energy companies- U.S. DRIVE) – GM, Ford, DOT, CaFCP, Exxon
- Fuel Cell and Hydrogen Energy Association (FCHEA)
- H2USA
- Various CDOs & SDOs (SAE, NFPA, ISO, CSA, ICC, etc)

National Collaborations (inter- and intra-agency efforts):

State & Regional Partnerships

- California Fuel Cell Partnership
- California Stationary Fuel Cell Collaborative
- Connecticut Center for Advanced Technology

National Laboratories

Lawrence Livermore
Los Alamos
NREL
Oak Ridge
Pacific Northwest
Sandia
Savannah River

Federal Agencies

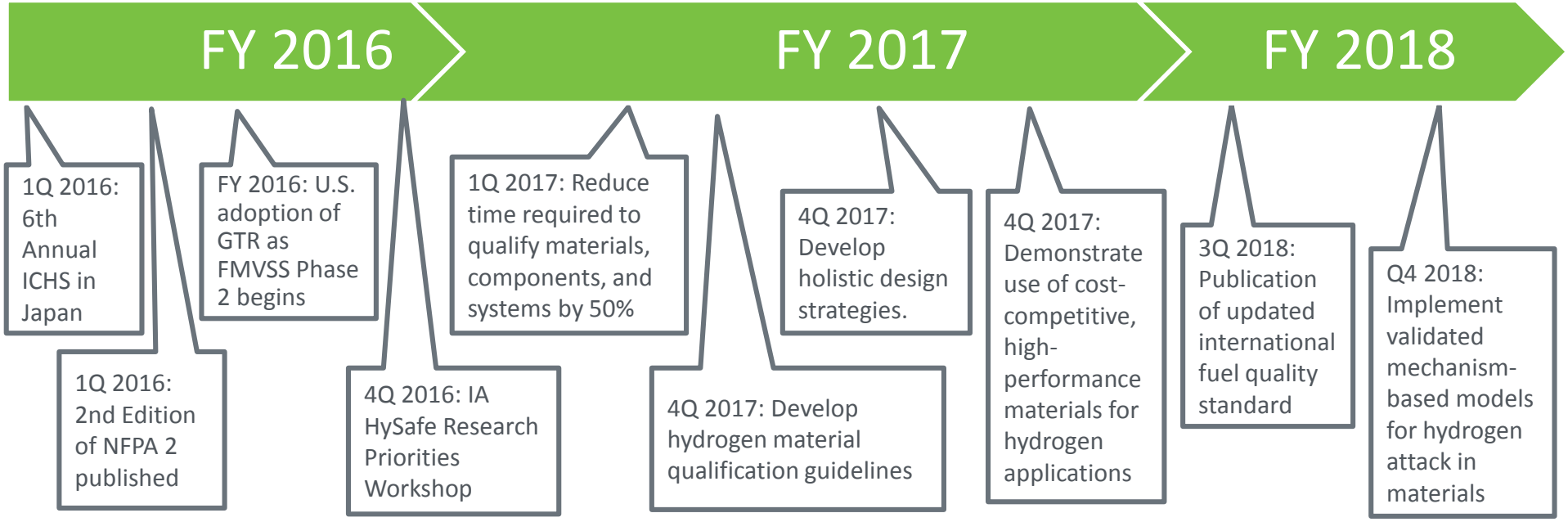
DOT NASA

- Interagency coordination through staff-level Interagency Working Group (meets monthly)
- Assistant Secretary-level Interagency Task Force mandated by EPACT 2005.

Summary

Summary of activities and upcoming milestones

- Decreasing hydrogen refueling station footprint by at least 5% for gaseous or liquid hydrogen delivery using a performance-based risk mitigation approach.
- Developing the initial liquid hydrogen release models that will inform the risk assessment for separation distances.
- Implementing QRA model to address structures such as enclosures, maintenance repair facilities, and bridges.
- Supporting coordination of state rollouts and public-private partnerships through
  - Outreach events for regional stakeholders to leverage deployment of hydrogen infrastructure.
  - Providing training to first responders and code officials regarding hydrogen and fuel technologies in the Northeast U.S. corridor



Thank you

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